LIFELINES AND CONTROL OF POST EARTHQUAKE FIRES

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Abstract

Reduction of direct and indirect earthquake losses requires that existing public works and utilities networks be functional following an earthquake. This requires both minimizing damages and planning and implementing practices for localizing effects of damages on network performance.

Earthquake damages will initiate fires which must be controlled and extinguished while small to avoid conflagrations such as those following the San Francisco 1906, Tokyo 1923 and Kobe 1995 earthquakes. This requires management of combustibles and reliable power, communication, transportation and water supply lifelines and well prepared fire services and general population.

There is need for a community and regional scale approach to achieve safe performance of public works and utilities and to plan land use and emergency management to control fires following earthquakes. These must be supported by technologies and practices for assessing and strengthening existing lifelines, by incentives for public officials and privately-owned utilities to take actions to improve the seismic performance of existing lifelines, and by advanced technologies supporting emergency activities.

The U.S.-Japan Earthquake Disaster Mitigation partnership should conduct cooperative activities to:

1. provide assessment and strengthening technologies for lifeline systems, including large scale testing, and development of recommendations for design guidelines, standards and practices.

2. define mechanisms and public policies to implement assessment and correction of dangerous public works and utilities.

3. develop and implement advanced technologies and practices for the emergency operation of damaged lifeline systems.

4. develop and implement advanced search and rescue and fire fighting and spread control techniques. This includes the development of improved models for predicting post-earthquake fire ignition and spread, and resident self-help techniques.

5. develop and implement private and public, regional and urban, planning and land use practices and incentives for reducing vulnerability to lifeline damages and fires following earthquakes.

6. Formalize the exchange of data and personnel for investigations of earthquakes that severely damage lifelines and/or cause substantial fires.

7. Develop or improve and implement loss estimation models to simulate disaster consequences and effects of control of post-earthquake fires.

Collaborative activities would be conducted under the auspices of the US/Japan Panel on Earthquake Prediction, US/Japan Panel on Fire Research and Safety, and US/Japan Panel on Wind and Seismic Effects.

I. Topic Description and Policy Issues

Lifelines are the public works and utilities (electrical power, communications, transportation, gas and liquid fuel, water supply and sewage) that support most human activities: family, economic, political and cultural. Experiences in recent earthquakes show that lifeline systems not designed and constructed for earthquake resistance are subject to failure during earthquakes. Direct losses can be catastrophic (consider the tens of thousands of people threatened by the failure of the Van Norman dam in San Fernando, California in 1971 [1][1]), and indirect losses can affect regions or whole nations (consider the widespread economic consequences of Japan's losses of high speed east-west rail service and container port facilities in Kobe in 1995 [2]).

Japan has endured catastrophic human and economic losses from fires following earthquakes in Tokyo 1923 and Kobe 1995. The United States suffered similar losses in San Francisco in 1906. Recent experiences in the United States (San Francisco 1989 and Northridge 1994) and Japan (Kobe 1995), even under no- or low-wind conditions, have shown inadequacies of fire safety systems in the time of greatest need following earthquake damages inducing fires. Electrical power, water supplies (including San Francisco's unique backup system developed after 1906), communications and transportation have been lost; failures of electrical power and gas and liquid fuel lifelines have initiated and fueled catastrophic fires; and search and rescue capabilities have been inadequate to remove people from damaged buildings prior to exposure to fire.

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[1] Numerals in brackets denote entries in Section VI, Key References

Our Nations' dependence on the reliable performance of lifelines in future earthquakes and our need to be able to control fires arising from earthquake damages lead to the following policy issues:

- Reduction of direct and indirect earthquake losses requires that existing public works and utilities networks be functional following an earthquake. This requires both minimizing damages and planning and implementing practices for localizing effects of damages on network performance.

- Earthquake damages will initiate fires which must be controlled and extinguished while small to avoid conflagrations such as those following the San Francisco 1906, Tokyo 1923 and Kobe 1995 earthquakes. This requires reliable power, communication, transportation and water supply lifelines and well prepared fire services and general population.

II. Background

Reduction of earthquake losses due to lifelines damages and fires following earthquakes requires a systems perspective. For instance, electrical power, communications, transportation, fuel, water supply and sewage are required for a hospital to provide emergency services to persons injured in an earthquake. An individual lifeline, such as electrical power, must not be so damaged locally that service is interrupted and must not be out of service because of remote damages. Advanced technologies and vigorous implementation efforts are required to assess and correct the vulnerabilities of lifelines.

Fire fighting services are tremendously stressed by responsibilities to: rescue persons trapped in damaged buildings and transportation facilities, learn about and prioritize responses to fires initiated by earthquake damages, reach fire scenes in spite of damages to transportation lifelines, and extinguish fires with available equipment and water supplies. Methods for estimating fire losses and accurate models of the spread of fires are needed for better preparedness and emergency management. Urban and regional planning are required to provide breaks to the spread of fires. Emergency planning and advanced technologies are required to prepare fire services, other public services and the general population to collaborate in the reduction of ignitions and control of the spread of fire.

The 1971 San Fernando, California earthquake demonstrated the vulnerability of modern urban areas to lifeline damages from earthquakes. Modern highway bridges collapsed, water supply and electricity were lost in the affected area, and dam failures threatened large losses of life and property [1]. This experience stimulated U.S. and Japanese studies of the performance and vulnerability of lifelines to: understand mechanisms of failure, and develop means to assess vulnerability and increase resistance. In 1974, the American Society of Civil Engineers established the Technical Council on Lifeline Earthquake Engineering to elevate the state of the art of lifeline earthquake engineering. In 1975, the topic *Disaster Prevention Methods for Lifeline Systems* was a theme for the 7th Joint Meeting of the U.S./Japan Panel on Wind and Seismic Effects; a task committee to address issues in this topic area was established by the Panel in 1976 [3].

In the United States, the National Science Foundation, the Federal Highway Administration, and the National Institute of Standards and Technology have sponsored much research on seismic performance of lifelines. Since its establishment in 1986, the National Center for Earthquake Engineering Research has devoted a major part of its research to lifelines. Other private sector organizations, such as the Applied Technology Council and Building Seismic Safety Council, have also in recent years been actively involved in advancing the state of the art practices of lifeline systems.

In Japan, the Public Works Research Institute and the Port and Harbor Research Institute have conducted substantial studies of lifelines performance. In addition to the reports of its joint meetings, the US/Japan Panel on Wind and Seismic Effects has sponsored six workshops on *Disaster Prevention Methods for Lifeline Systems* whose reports document the results of the studies conducted by U.S., Japanese and other nations' researchers. Some key publications summarize the performance of lifelines systems in recent earthquakes as well as the state of the art of knowledge and practice for lifeline earthquake engineering are given in Section VI, Key References [4, 5, and 6].

Studies of lifelines performance in recent earthquakes show that, while much remains to be learned about earthquake effects on lifelines, lifelines well designed to resist earthquakes perform well in severe earthquakes. For instance, San Francisco's Bay Area Rapid Transit system, which received special attention to seismic safety during its design, was functional immediately after the 1989 earthquake. Yet in the United States, nationally recognized guidelines and standards for existing and new lifelines are available only for highway bridges, nuclear reactors and dams. These are the areas where federal initiative has been taken to support guidelines and standards development. The United States recently has prepared a *Plan for Developing and Adopting Seismic Design Guidelines and Standards for Lifelines* [7], but implementation of the plan is just beginning. Japan's studies have led to practices such as its *Manual of Repair Methods for Civil Engineering Structures Damaged by Earthquakes*, but damages to both older and modern lifelines observed in Kobe in 1995 also show needs to improve Japanese lifeline standards.

Seismic safety is but one of the many problems facing owners and managers of both private and public works and utilities. To achieve seismic safety reliably and efficiently, seismic safety practices must be integral with normal practices of construction, normal and emergency operations, maintenance, and renovation. Advanced risk and loss estimation techniques, described in an accompanying symposium paper by Dr. Robert Whitman, will make clear to customers and managers the benefits of implementing loss reduction practices for lifelines.

The U.S. federal government has responsibility and authority for implementation of practices for the seismic safety of lifelines that are federally owned or federally regulated for safety. Moreover, implementation of seismic safety practices for state or local government and private lifelines can be encouraged by making it a condition for federal aid. Policy precedents of U.S. Executive Order 12699, *Seismic Safety of Federal and Federally Assisted or Regulated New Building Construction*, and Executive Order 12941, *Seismic Safety of Existing Federally Owned or Leased Buildings*, show how federal programs and authorities can provide incentives and requirements for implementation of seismic safety practices by state and local

governments and by the private sector.

Public safety and the control of post earthquake fires benefit from improved reliability of buildings and lifelines, but it is inevitable that a severe earthquake will cause localized building and lifeline damages that injure people and initiate fires. Effective management of the fire services will be required to locate and rescue injured and trapped persons and to find and combat fires. Effective alternate water supplies for local fire fighting and technology that enhances its ability to control fire spread are needed for both resident self-help and professional use. Emergency lifeline operations will be needed to isolate damaged elements of the systems and make communications, power, transportation and water available for search and rescue and fire fighting. Residents should be trained and prepared for self-help for fire fighting activities.

Accompanying symposium papers by Dr. Mori, Dr. Cluff and Mr. Baughman describe the abilities of real time damage estimation and the Cooperative U.S./Japan Development of Real-time Seismic Information Systems that have features to support these emergency activities and the policy issues that must be addressed to achieve these capabilities. In addition, state of the art technologies for search and rescue must be widely implemented through equipping and training search and rescue teams. Improved sensors and debris removal tools also are needed.

Similarly, the state of the art of sensing and control techniques for operating damaged lifelines must be codified and widely implemented, and research should be focused on most important needs for sensing, control and repairs.

Special fire fighting techniques are needed to address conflagrations rather than individual building fires [8]. U.S. and Japanese experiences should be assessed and recommended techniques and practices disseminated to fire services and general population. Research should be focused on most needed technologies and practices. Land use practices are important to achieve passive barriers to fire spread. These include both control of constructed facilities and natural vegetation.

III. Proposal

The US/Japan Earthquake Disaster Mitigation Partnership provides an extraordinary opportunity to reduce both nations' and the world's vulnerability to catastrophic earthquake losses. Moreover, the United States and Japan can expeditiously and economically develop the needed technologies and practices by coordinating research and development efforts and continuing to learn together from earthquake experiences. Seven policy recommendations are important for Earthquake Resistant Design, Construction, Rehabilitation and Repair Standards for lifelines and control of fires:

1. provide assessment and strengthening technologies for lifeline systems, including large scale testing, and development of recommendations for design guidelines, standards and practices.

2. define mechanisms and public policies to implement assessment and correction of dangerous public works and utilities.

3. develop and implement advanced technologies and practices for the emergency operation of damaged lifeline systems.

4. develop and implement advanced search and rescue and fire fighting and spread control techniques. This includes the development of improved models for predicting post-earthquake fire ignition and spread, and resident self-help techniques.

5. develop and implement private and public, regional and urban, planning and land use practices and incentives for reducing vulnerability to lifeline damages and fires following earthquakes.

6. Formalize the exchange of data and personnel for investigations of earthquakes that severely damage lifelines and/or cause substantial fires.

7. Develop or improve and implement loss estimation models to simulate disaster consequences and effects of control of post-earthquake fires.

IV. Cooperative Mechanisms

Existing, effective collaboration mechanisms under the U.S.-Japan Program on Natural Resources (UJNR) provide an excellent framework for addressing these policy recommendations. The UJNR Panels active in the area are:

- Earthquake Prediction Technology (EPT)
- Fire Research and Safety (FRS)
- Wind and Seismic Effects (WSE)

Assessment and strengthening technologies for lifeline systems can be addressed by collaborative efforts of EPT and WSE in the characterization of the earthquake hazard, and by WSE for vulnerability and strengthening. Enhanced involvement of private sector and academic experts is critical to the success of these collaborations.

Mechanisms and public policies to implement assessment and correction of dangerous public works and utilities can be addressed by WSE with enhanced involvement of federal, state, local and private officials representing lifelines' owners and managers and of academic experts in public policies.

Advanced technologies and practices for the emergency operation of damaged lifeline systems can be addressed by WSE and FRS with enhanced involvement of experts with operational roles in federal, state, local and private lifelines and of fire services.

Advanced search and rescue and fire fighting techniques can be addressed by FRS with involvement of search and rescue experts and manufactures of search and rescue and fire fighting equipment.

Private and public, regional and urban, planning and land use practices and incentives for reducing vulnerability to lifeline damages and fires following earthquakes can be addressed by WSE and FRS with involvement by public agencies, industry associations and academic experts concerned with land use and planning.

Formalization of collaboration in post-earthquake investigation will involve all three panels.

Improvement of loss estimation modeling also will involve all three panels.

V. Related Issues

Seismic safety standards and practices for lifelines and control of fires relate closely to other topics of the Symposium. Seismic hazard mapping is essential to provision of adequate strength for lifelines. Earthquake loss estimation methods will define the cost effective investments in strengthening existing lifelines and for improving capabilities to control post-earthquake fires. Real time monitoring and warning systems are vital to lifelines' operations. Disaster situation assessments will guide lifelines' operations, search and rescue and fire fighting. Common technologies apply to assessment and strengthening of buildings and lifelines. Lifelines' performance and control of fires are critical to overall earthquake response and recovery activities. The Symposium will seek an integrated set of policy recommendations accounting for these interrelations.

VI. Key References

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